

Claims

1 1. A method of modifying a virtual object stored within a computer, the method comprising the
2 steps of:

3 representing a virtual object as a volumetric model;
4 converting a subset of the volumetric model into an alternative representation;
5 determining a response of the alternative representation to a stimulus; and
6 modifying the volumetric representation so as to substantially represent the response of
7 the alternative representation to the stimulus.

1 2. The method of claim 1, wherein determining a response of the alternative representation
2 to a stimulus comprises determining a response of the alternative representation to a first
3 stimulus and further determining a response of the alternative representation to a second
4 succeeding stimulus.

1 3. The method of claim 1, wherein modifying the volumetric representation comprises a
2 change in shape of the volumetric representation.

1 4. The method of claim 1, wherein modifying the volumetric representation comprises
2 converting the response of the alternative representation to the stimulus into a response of the
3 volumetric representation to the stimulus.

1 5. The method of claim 1, wherein the subset of the volumetric model is the entire
2 volumetric model.

1 6. The method of claim 1, wherein the subset of the volumetric model is a portion of the
2 volumetric model.

1 7. The method of claim 1, wherein the volumetric model comprises voxels.

1 8. The method of claim 1, wherein the volumetric model comprises values spaced in a three-
2 dimensional grid.

1 9. The method of claim 1, wherein the alternative representation comprises a surface
2 representation.

1 10. The method of claim 1, wherein the alternative representation comprises a set-of-triangles
2 representation.

1 11. The method of claim 10, wherein the stimulus comprises a weighted displacement
2 function defined on vertices of the set-of-triangles representation.

1 12. The method of claim 1, wherein the alternative representation comprises a selected one of
2 a polygon set, a bezier surface, a b-spline surface, a procedural surface, and a NURBS
3 representation.

1 13. The method of claim 1, wherein the alternative representation comprises an alternative
2 voxel representation.

1 14. The method of claim 1, wherein the stimulus is a stimulus from a user using a haptic
2 interface.

1 15. The method of claim 14, wherein the haptic interface is a force feedback interface.

1 16. The method of claim 14, wherein the haptic interface has at least three degrees of force
2 feedback.

1 17. The method of claim 1, further comprising the step of displaying the virtual object on a
2 computer display.

- 1 18. The method of claim 1, wherein the volumetric representation and the alternative
- 2 representation comprise representations having different numbers of dimensions.

- 1 19. The method of claim 1, wherein the applied stimulus comprises at least one of a
- 2 displacement function, a smoothing function, a warping function, a volumetric interference, an
- 3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a
- 4 force.

- 1 20. The method of claim 1, wherein the applied stimulus is applied to the object in real time.

- 1 21. The method of claim 1, further comprising the steps of:
 - 2 transforming the alternative representation into a third representation;
 - 3 modifying the third representation in response to an applied stimulus; and
 - 4 transforming the modified third representation to a modified volumetric representation.

- 1 22. The method of claim 21, wherein transforming the modified third representation to the
- 2 modified volumetric representation comprises generating an intermediate modified
- 3 representation.

- 1 23. The method of claim 1, wherein the stimulus comprises a user motion in the at least
- 2 three-dimensional space.

- 1 24. The method of claim 1, further comprising applying a feedback force to a user, the
- 2 feedback force being generally consistent with a geometric shape of a modified virtual object.

- 1 25. A method of modifying a volumetric representation of an object, the method comprising
- 2 the steps of:
 - 3 transforming at least a portion of the volumetric representation into a polygonal set
 - 4 representation;
 - 5 modifying the polygonal set representation; and

6 modifying the volumetric representation to substantially represent the modification made
7 to the polygonal set representation.

1 26. The method of claim 25, wherein the modification comprises a selected one of a
2 displacement function, a smoothing function, a warping function, a volumetric interference, an
3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a
4 force.

1 27. A method of modifying a volumetric representation of an object, the method comprising
2 the steps of:

3 transforming at least a portion of the volumetric representation into a surface-based
4 representation;
5 modifying the surface-based representation; and
6 modifying the volumetric representation to substantially represent the modification made
7 to the surface based representation.

1 28. A system for modifying a virtual object stored within a computer, the system comprising:
2 a representation module that represents a virtual object as a volumetric model;
3 a conversion module that converts a subset of the volumetric model into an alternative
4 representation;
5 an analytic module that determines a response of the alternative representation to a
6 stimulus; and
7 a modification module that modifies the volumetric representation so as to substantially
8 represent the response of the alternative representation to the stimulus.

1 29. The system of claim 28, wherein the analytic module that determines a response of the
2 alternative representation to a stimulus comprises an analytic module that determines a response
3 of the alternative representation to a first stimulus and further determines a response of the
4 alternative representation to a second succeeding stimulus.

1 30. The system of claim 28, wherein the modification module that modifies the volumetric
2 representation comprises a modification module that changes a shape of the volumetric
3 representation.

1 31. The system of claim 28, wherein the modification module that modifies the volumetric
2 representation comprises a modification module that converts the response of the alternative
3 representation to the stimulus into a response of the volumetric representation to the stimulus.

1 32. The system of claim 28, wherein the subset of the volumetric model is the entire
2 volumetric model.

1 33. The system of claim 28, wherein the subset of the volumetric model is a portion of the
2 volumetric model.

1 34. The system of claim 28, wherein the volumetric model comprises voxels.

1 35. The system of claim 28, wherein the volumetric model comprises values spaced in a
2 three-dimensional grid.

1 36. The system of claim 28, wherein the alternative representation comprises a surface
2 representation.

1 37. The system of claim 28, wherein the alternative representation comprises a set-of-
2 triangles representation.

1 38. The system of claim 37, wherein the stimulus comprises a weighted displacement
2 function defined on vertices of the set-of-triangles representation.

1 39. The system of claim 28, wherein the alternative representation comprises a selected one
2 of a polygon set, a bezier surface, a b-spline surface, a procedural surface, and a NURBS
3 representation.

1 40. The system of claim 28, wherein the alternative representation comprises an alternative
2 voxel representation.

1 41. The system of claim 28, wherein the stimulus is a stimulus from a user using a haptic
2 interface.

1 42. The system of claim 41, wherein the haptic interface is a force feedback interface.

1 43. The system of claim 41, wherein the haptic interface has at least three degrees of force
2 feedback.

1 44. The system of claim 28, further comprising a display module that displays the virtual
2 object on a computer display.

1 45. The system of claim 28, wherein the volumetric representation and the alternative
2 representation comprise representations having different numbers of dimensions.

1 46. The system of claim 28, wherein the applied stimulus comprises at least one of a
2 displacement function, a smoothing function, a warping function, a volumetric interference, an
3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a
4 force.

1 47. The system of claim 28, wherein the applied stimulus is applied to the object in real time.

1 48. The system of claim 28, further comprising:

2 a second transformation module that transforms the alternative representation into a third
3 representation;
4 a third modification module that modifies the third representation in response to an
5 applied stimulus; and
6 a third transformation module that transforms the modified third representation to a
7 modified volumetric representation.

1 49. The system of claim 48, wherein the third transformation module that transforms the
2 modified third representation to the modified volumetric representation comprises a
3 transformation module that generates an intermediate modified representation.

1 50. The system of claim 48, wherein at least two of the first, second and third modification
2 modules are the same module.

1 51. The system of claim 48, wherein at least two of the first, second and third transformation
2 modules are the same module.

1 52. The system of claim 28, wherein the stimulus comprises a user motion in the at least
2 three-dimensional space.

1 53. The system of claim 28, further comprising a force feedback module that applies a
2 feedback force to a user, the feedback force being generally consistent with a geometric shape of
3 a modified virtual object.

1 54. A system of modifying a volumetric representation of an object, the system comprising:
2 a transformation module that transforms at least a portion of the volumetric representation
3 into a polygonal set representation;
4 a first modification module that modifies the polygonal set representation; and
5 a second modification module that modifies the volumetric representation to substantially
6 represent the modification made to the polygonal set representation.

1 55. The system of claim 54, wherein a selected one of the modification of the polygonal set
2 representation and the modification of the volumetric representation comprises a selected one of
3 a displacement function, a smoothing function, a warping function, a volumetric interference, an
4 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a
5 force.

1 56. A system of modifying a volumetric representation of an object, the system comprising:
2 a transformation module that transforms at least a portion of the volumetric representation
3 into a surface-based representation;
4 a first modification module that modifies the surface-based representation; and
5 a second modification module that modifies the volumetric representation to substantially
6 represent the modification made to the surface based representation.